Combining Ability And Inheritance Of Growth Traits In Rabbits

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Abstract
New Zealand Red, Californian White and Chinchilla rabbit's growth performance traits were evaluated using diallel analysis. Data on body linear measurements were analysed by partial diallel analysis. The data were first corrected for significant effect of animals' sex using least squares constants while effects of months of birth of the kittens and their does' age were not significant. The results showed that General and Specific Combining Ability (GCA) were significant for all traits measured. Both additive and non-additive effects influenced the performance of the hybrid in all the traits. The non-additive effects played a more important role than additive effects in body weight, height at withers and trotter length and additive effects were more important for ear length, body length, breast girth and tail length. The New Zealand Red and Californian White parents were found as the reliable general combiner. The reciprocal effect was not found to be significant for all traits. Therefore, use of separate male and female breeds of rabbit in any crossbreeding programme may not accumulate additional advantage.
Keywords: General Combining Ability, Heritability, Rabbit, Specific Combining Ability,

Introduction

Rabbit is a micro livestock species which has a number of characteristics that makes it a desirable meat producing animal. This species needs less space and smaller feed due to small body size, shorter generation interval, high prolificacy, faster growth rate and high feed conversion efficiency are the qualities that have made rabbit ideal specie for meat production (Bora *et al*., 2010) compare to other livestock species. The world rabbit meat production was 1,668,400 tonnes, with China being the largest producer with 663,000 tonnes, followed by European Union with 472,648 tonnes (FAO-STAT, 2010). The production of rabbit is meat very efficient, as 20% of the proteins consumed are converted into edible protein (Mohamed, 2012). Improvement in the performance of rabbit breeds can be achieved through selection or crossbreeding. Extra benefits can be obtained from heterosis and from the break of the cumulated inbreeding which may have occurred during the selection process. Genetic improvement of growth performance traits and selection in breeding programmes depends on precise estimates of genetic variation for the traits of interest which consists of additive, dominance and epistasis effects.

One of the several biometrical procedures available to animal breeders for evaluating and characterizing genetic variability existing in animal species is diallel analysis. The diallel cross has become a common method of analysing genetic variability among combinations of breeds and their crosses and is an important method for the evaluation of combining abilities, heterosis and inheritance of traits (Rehman *et al*., 2009; Lawati *et al*., 2010). The performance of all crosses that derive from one breed is called general combining ability (GCA) of the breed, while the specific combining ability (SCA) is the joint attribute of two breeds and signifies the deviation of a cross from the sum of the GCA's of its parent strains (Pirchner, 1983). Reciprocal effects (RE) (sex-linked effects) measures the residual difference between reciprocal crosses after taking into account general and specific combining abilities into consideration (Afifi and Emara, 1990).

In Nigeria, there are several breeds of rabbits available to the producers; however, diallel crosses with rabbits to evaluate their performance in the various combinations have not been carried out to date. Also, information on the additive and non-additive effects on body weight and body linear measurements of rabbit kittens is scarce. Hence, this investigation was undertaken to study the genetic and non-genetic factors affecting the growth performance traits of crossbred (F_1) rabbits in a diallel experiment.

Materials and Methods

This research was carried out in the Experimental Rabbit Unit of the Teaching and Research Farms Directorate, Federal University of Agriculture, Alabata Road, Abeokuta, Nigeria. The climate is classified as tropical, with a mean annual rainfall of about 1037mm. The mean ambient temperature ranges from 28°C to 36°C with a yearly average relative humidity of about 82%. The rabbits were raised under intensive system. Data for this study was collected on 138 kittens from 30 does and 6 sires of New Zealand Red, Californian White and Chinchilla breeds from October, 2011 to March, 2012. Rabbits were kept indoors, in individual wire cages that were equipped with a nipple drinker and a feeder placed outside the cage. The rabbits had *ad libitum* access to feed and water. They were fed a commercial pelleted diet with 14% CP and 16% CF offered twice a day. Common sanitary practices were carried out to ensure good health status of the rabbits.

The Experimental Rabbits

The experimental rabbits consisted of six lines inclusive of straight and reciprocal crosses generated from crossing of the different breeds. Thirty (10 does per breed) growing rabbits averaging between 26 and 28 weeks of age and weighing 950g to 1200g were mated with six bucks (2 bucks per breed) of the same age. The bucks and does were randomly selected from each breed and used as parents, and the kittens are classified according to the genotype of sire and dams as shown below:

Categories of straight crosses (Mating of a buck with five does for each crosses)
Californian White (CW) × New Zealand Red (NZR) = CW × NZR
Californian White (CW) ×Chinchilla (CH) = CW × CH
New Zealand Red (NZR) x Chinchilla (CH) = NZR × CH

Categories of reciprocal crosses (Mating of a buck with five does for each crosses)
New Zealand Red (NZR) x Californian White (CW) = NZR × CW
Chinchilla (CH) x Californian White (CW) = CH × CW
Chinchilla (CH) x New Zealand Red (NZR) = CH × NZR
The sire breed is shown first.

Data Collected

Newly kindled kittens from the different genotypes were weighed on weekly basis from birth till post weaning age of 84 days. Measurements were taken on other linear body parameters with the aid of a measuring tape. All body measurements were taken in the morning before the animals were fed. Only measurements taken at 84 days were analysed in this study. Parameters measured include:
Body weight (BW): - This was measured with the use of weighing scale of 0.05g sensitivity.
Ear length (EL): - This was measured as the distance from the point of attachment of the ear to the tip of the ear.
Breast girth (BG): - This was measured as the circumstance of the breast around the chest region.
Height at withers (HW): - This was measured as the distance on the dorsal midline of the high point on the withers.
Tail length (TL): - This was measured as the distance in (cm) from the end of the lumber vertebrae to the end of caudal vertebra (extremes).
Trotter length (TRL): - This was measured as the average distance between the attachment of the fore and hind legs to the top of the claws.
Body length (BL): - This was measured as the distance between the nose and the end of the lumber vertebrae.

Statistical Analysis

An analysis of variance (ANOVA) was conducted for data collected. The data were first corrected for significant effect of kittens' sex using least squares constants (Harvey, 1975) before the diallel analysis, while effects of months of birth of the kittens and their does' age were not significant.. A SAS (SAS Institute, Cary, North Carolina) programme () for the diallel analysis was used to estimate GCA, SCA and RE effects for linear body measurements. Estimates of GCA, SCA and RE effects were based on the Griffing's (1956) method 3, model 1. The model of the combining ability analysis assumed is as follows:

$Y_{ijk} = \mu + g_i + g_j + s_{ij} + r_{ij} + e_{ijk}$

Where: Y_{ijk} is variable analysed
μ is overall mean
g_j is the effect of the general combining ability of the i^{th} breed
g_j is the effect of the general combining ability of the j^{th} breed
S_{ij} is the effect of the specific combining ability of the cross (i, j)
r_{ij} is the reciprocal (sex–linked) effect of the cross (i, j)
e_{ijk} is the random error assumed to be independently randomly distributed (σ, σ^2).

The relative importance of GCA and SCA effects on inheritance of the linear body measurements was evaluated using the formula 2GCA/ (2GCA + SCA) (Baker, 1978). The closer this ratio is to 1, the more important the additive gene effects are in inheritance of the trait. Heritability was calculated using the formula $h_n^2 = \sigma_A^2/\sigma_p^2$
Where h_n^2 = heritability, σ_A^2 = additive genetic variance (2GCA), σ_p^2= total phenotypic variance

Results and Discussion

The present study provides a good understanding of the performance of 3 breeds of rabbit in a diallel mating design. The least square means of the effect of genotypes on body linear measurements and body weight is shown in Table 1. The significant variance between the genotypes indicates considerable genetic diversity among the straight crosses and their reciprocal crosses. Results obtained from analysis of variance for body linear measurements and body weight (Table 2) showed that all the traits were influenced ($P<0.001$) by general combining ability and specific combining ability showing the importance of both additive and dominance gene effects. This meant significant additive and non-additive genetic variance as regards to body weight and body linear measurements in these 3 breeds of rabbits. The significant GCA mean squares for all traits indicated variability of GCA among the parents and this suggests that genetic gain is achievable through selection in the segregating population.

General combining ability (GCA)

The estimates of GCA effects ranged from -1.86 to 2.53 for BW, from -0.21 to 0.20 for EL, from -2.07 to 1.29 for BG, from -0.97 to 1.72 for HW, from -1.69 to 3.24 for TL, from -1.20 to 0.70 for TRL and from -1.06 to 0.78 for 0.28 BL. This study shows positive GCA effect for body weight, ear length, body girth, trotter length, body length of New Zealand Red, while negative GCA effect for height at wither, tail length (Table 3). Also, there was positive GCA effect on breast girth, trotter length and body length of Chinchilla but negative GCA effect on body weight, ear length, height at wither and tail length. In the Californian White, positive GCA influence was observed on ear length, height at wither and tail length; while negative GCA influence was observed on body weight, breast girth, trotter length and body length. New Zealand Red had the highest GCA effects on body weight, breast girth, trotter length and body length resulting from high selection pressure which reduced variation. On the other hand, Californian White had the lowest GCA effects on body weight, breast girth, trotter length and body length. This indicates the inferior performance of this breed in its hybrid combination for mentioned traits compared to New Zealand Red. The Chinchilla breed shows low but positive GCA effects for trotter length and the body length indicating good hybrid abilities and higher gene variations for these traits, indicative of opportunity for improvement. Therefore, maximum utilization of additive genetic variance could be achieved by using both Chinchilla and New Zealand rabbits for an improved body weight, breast girth, trotter length and body length which are economically important body measurements traits in any improvement programme.

Specific Combining Ability (SCA)

Results for SCA showed that the combinations CH-NZR was superior for body weight, height at wither and tail length, while combinations of CA-CH was superior for other body measurement traits in this study. These results do not agree with those of Carregal (1980) and Afifi and Emara (1990) who reported non-significant differences due to SCA for kitten body weight at different ages for CA-CH. This may be due to differences in the genetic differences within the breeds after 20 years selection of the breeds used in the various studies. The estimates of SCA for body weight (-8.91 to 3.51), breast girth (-1.66 to 4.55) and trotter length (-4.01 to 3.29) were high. This non-additive hereditary interaction may be an important source of variance among individuals without major influence upon family performance. In all traits measured, non-additive gene effects were more important for the ear length while it was less important in other traits. Therefore, individual specifics control these traits. This will most likely be as a result of non-specific selection pressure for these traits as suggested by Adebambo *et al. (*2010). Observations on SCA results also indicated that CH-NZR and CA-CH crosses had the best individual crossbred performance in the aforementioned traits and therefore would be good crosses for improvement in body measurements.

The results of effects of GCA and SCA on body measurement traits were in agreement with report of Gupta *et al.* (1999) who observed moderate effect of SCA on weaning weight of New Zealand White, Chinchilla and Flemish Giant while on the basis of the results of a 4x4 diallel crossing experiment, Nagpure *et al*. (1991) observed significant role of GCA and SCA on growth parameters.

In this study, additive and non- additive gene effects were important in genetic control for all traits. Baker (1978) suggested the use of ratio of mean squares 2GCA/ (2GCA +SCA) to determine the relative importance of the additive gene effects. None of the ratios of GCA to SCA was close to one. This implies that non-additive gene effects are more important than additive gene effects in inheritance of the traits. Hence, crosses involving genotypes with higher estimates of GCA for each trait should be potentially superior for the selection of breeds in consequent generations.

Evidence that both additive and non-additive gene effects are involved in the genetic control of the traits investigated implies that both types of gene effects should be considered when setting up breeding schemes for the selection of superior breeds.

Reciprocal effects

The reciprocal effect was not found to be significant for all traits. This means that use of separate male and female lines in any crossbreeding programmes will not accumulate additional advantage for improvement.

Estimate of Heritability

Narrow sense heritability (h^2_n) ranged from 0.01 to 0.49 for the body measurement traits (table 4). Body weight had highest h^2_n while trotter length had the lowest value. Only body weight had medium h^2_n while other traits had low h^2_n. This means that considerable progress can be made by selecting individuals on the basis of their own performance for body weight while the low h^2_n in other traits implies that family selection is more appropriate to bring about faster genetic progress in these traits.

Conclusion

Evidence that additive and non-additive gene effects are involved in the investigated traits should be considered when developing new breeding schemes to select superior breeds. No significant reciprocal effect was found for all the traits suggesting that any breed can be chosen as dam and sire and choice of parents is not critical for these traits. The best general combiner were New Zealand Red for body weight, breast girth, trotter length and body length while Californian White should be selected ear length, height at wither and tail length. These breeds can be incorporated into rabbit breeding programmes using most appropriate selection methods that take advantage of the GCA and SCA.

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Table 1: Least squares means of crosses showing effect of genotype on body linear measurement and body weight of rabbits in a diallel experiment.

Sire breed	Dam breed	No TL	BG	EL	BW		TRL	HW	BL
NZR	CH	24	26.00±0.19***	10.73±0.08***	853.34±32.89***	24.47±0.25***	10.17±0.08***	34.60±0.39***	9.97±0.07***
CH	NZR	20	23.93±0.49***	9.88±0.14***	865.99±39.33***	23.57±0.30***	9.85±0.15***	33.19±0.87***	9.47±0.19***
CH	CW	24	25.76±1.29***	9.88±0.25***	795.12±23.32***	23.82±0.53***	9.54±0.27***	32.15±0.90***	9.54±0.27***
NZR	CW	25	26.91±0.33***	10.97±0.17***	853.17±22.09***	11.03±0.21***	10.17±0.10***	35.71±0.24***	11.65±0.10***
CW	CH	22	24.39±0.22***	9.96±0.06***	736.07±22.36***	23.32±0.17***	11.29±0.17***	31.43±0.46***	8.56±0.11***
CW	NZR	23	22.76±0.47***	9.32±0.17***	791±66±47.27***	22.77±0.79***	0.64±0.89***	33.18±0.42***	9.14±0.27***

***P<0.001; NZR=New Zealand Red; CH=Chinchilla; CW=Californian White.

Table 2: Analysis of variance for combining abilities of body weight and linear body measurements

Source of variance	BG		EL		BW		TLR				HW		BL	
	TL													
	df	ms	df	ms	df	ms	df	ms	df	ms	df	ms	df	ms
GCA	2	2761.59	2	38.43	2	4945.42	2	913.52	2	1858.16	2	786.78	2	6569.72
SCA	3	4513.00	3	27.49	3	25320.65	3	7148.91	3	6338.59	3	650.68	3	6980.37
RE	3	618.03	3	39.13	3	79097.42	3	2486.18	3	4730.16	3	381.29	3	559.38
Error	130	23.07	130	3.06	130	69512.7	130	19.58	130	11.68	130	38.53	130	9.02

Table 3: General combining ability and Specific combining ability for growth traits

Parameters	BG	EL	BW	TLR	HW	BL	TL
Gc	0.77***	-0.21***	-0.66***	0.49***	-0.75***	0.28***	-1.55***
Gn	1.29***	-0.01***	2.53***	0.70***	-0.97***	0.78***	-1.69***
Gb	-2.07***	0.20***	-1.86***	-1.20***	1.72***	-1.06***	3.24***
Snb	-1.66***	0.14***	3.51***	-4.01***	4.03***	-0.92***	2.64***
Sbc	4.55***	0.33***	-11.11***	3.29***	-1.84***	1.47***	-4.90***
Snc	0.24***	0.29***	-8.91***	2.46***	-2.33***	1.15***	-4.55***
Rnb	-1.01 ^{NS}	-0.33 ^{NS}	7.35 ^{NS}	4.32 ^{NS}	-6.06 ^{NS}	1.75 ^{NS}	-0.66^{NS}
Rbc	-4.35 ^{NS}	-1.04 ^{NS}	-19.54 ^{NS}	2.31 ^{NS}	-3.29 ^{NS}	-0.59 ^{NS}	4.25 ^{NS}
Rnc	-3.95 ^{NS}	-0.65 ^{NS}	26.10 ^{NS}	3.20 ^{NS}	-3.46 ^{NS}	0.07 ^{NS}	4.34 ^{NS}

***P<0.001 NS=Non significant Gc=General combining ability for Chinchilla, Gn= General combining ability for New Zealand Red; Gb=General combining ability for Californian White Snb= Specific combining ability for

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New Zealand Red and Californian White Sbc= Specific combining ability for Californian White and Chinchilla; Snc=Specific combining ability New Zealand Red and Chinchilla; Rnb= Reciprocal effect for New Zealand Red and Californian White; Rbc= Reciprocal effect for Californian White and Chinchilla; Rnc= Reciprocal effect for New Zealand Red and Chinchilla.

Table 4: Heritability and ratio of General combining and specific abilities of body linear measurements of three rabbit breeds

Traits	Heritability	2GCA/ (2GCA + SCA)
BG	0.04	0.55
EL	0.14	0.74
BW	0.49	0.28
TLR	0.01	0.20
HW	0.02	0.37
BL	0.13	0.71
TL	0.08	0.65

Figure 1: a= New Zealand Red b= Chinchilla and Californian White hybrid c=Chinchilla d=Californian white e=crossbred of New Zealand Red and Californian white